SYNTHETIC BIOLOGY IN BIOMANUFACTURING – ARE WE READY FOR IT ?

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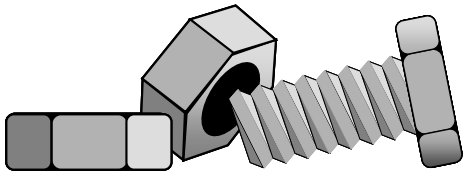
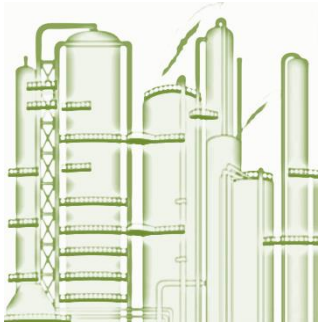
OECD
BETTER POLICIES FOR BETTER LIVES

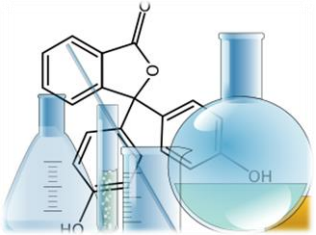
Bioeconomy nuts and bolts

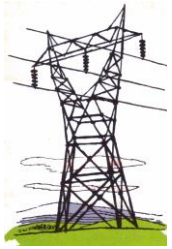


- **Decouple economic growth from environmental degradation**
  - Doubling of wealth has historically been linked to an 80% increase in emissions
- In particular the need to **drastically cut GHG emissions**
- Biotechnology will be used in the development of all pharmaceuticals and most new varieties of large market crops

Sustainable biomass

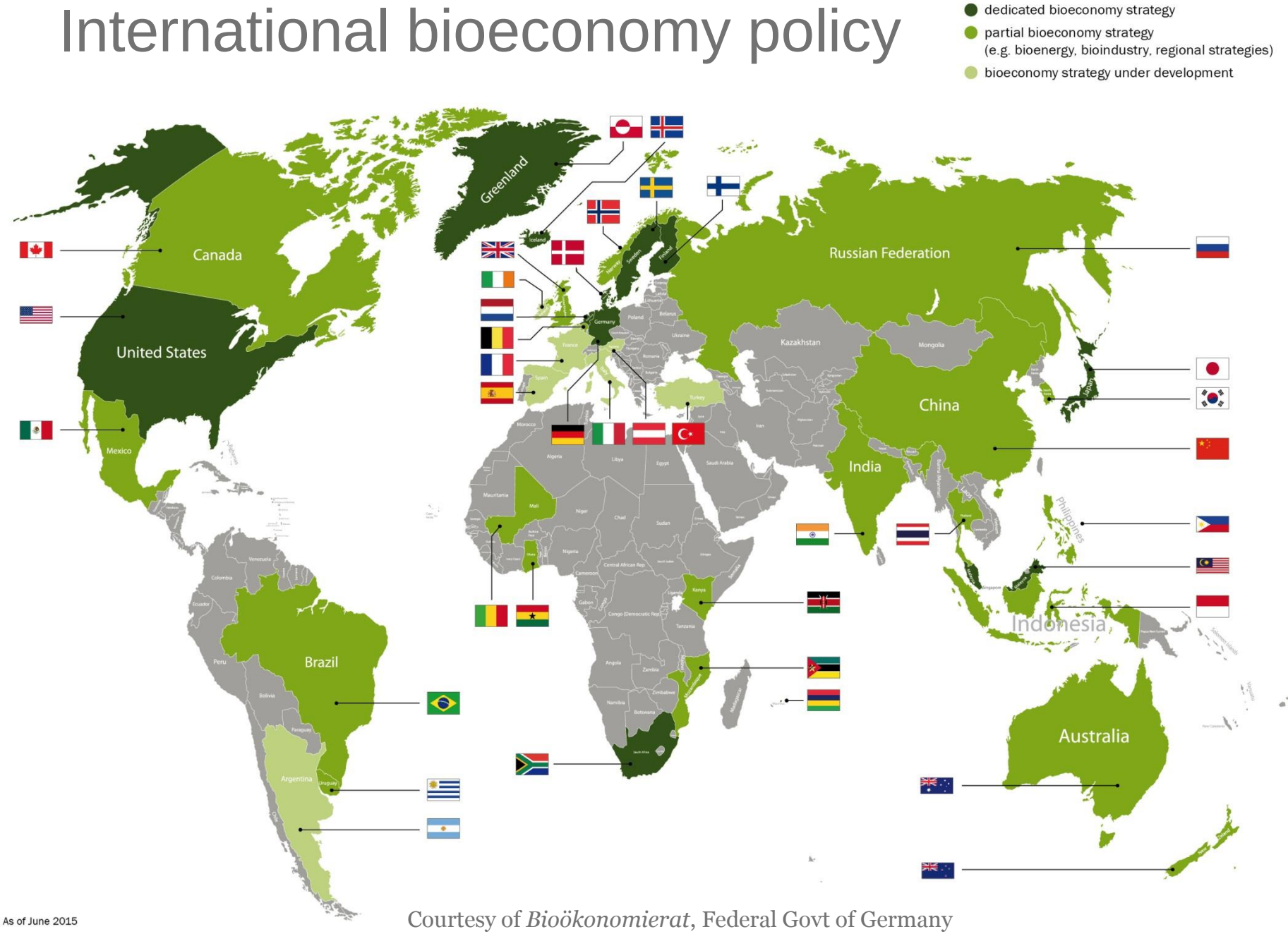






OECD (2009). *The Bioeconomy to 2030: Designing a Policy Agenda*. OECD Publishing, Paris.

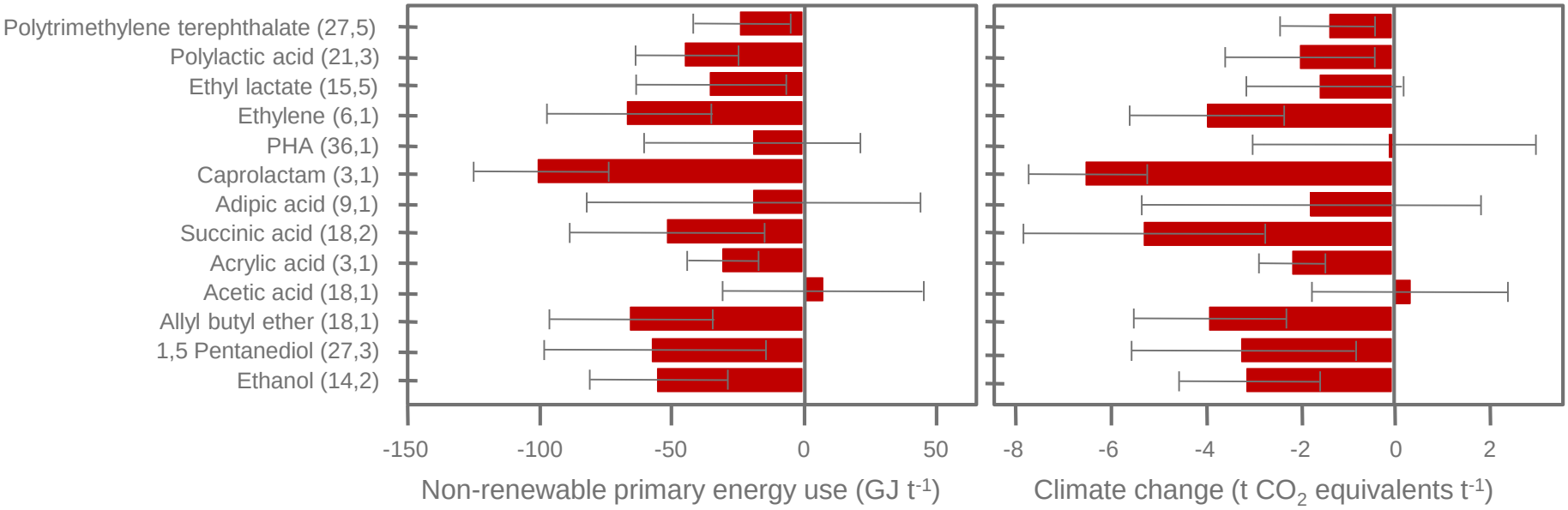
International bioeconomy policy



As of June 2015

Courtesy of *Bioökonomierat*, Federal Govt of Germany

Environmental impacts of bio-based products



- Bio-based production holds great promise

BUT

- No accepted international standards for GHG emissions savings for bio-based chemicals and plastics

Weiss et al. (2012). *Journal of Industrial Ecology* 16, Supplement S1, S169–S181

Attention Europe: chemicals industry is threatened

- Chemical industry has long been a cornerstone of European economies
- In 2013, EU chemicals sales accounted for over 7% of EU manufacturing output
- Direct chemical jobs in EU: about 1.2 million in 2012
- Chemistry creates up to x 7.6 jobs in other sectors

Country/region	Competitiveness rank in 1992	Competitiveness rank in 2012
Saudi Arabia	4	1
US	1	2
India	6	3
EU	3	4
China	7	5
Japan	2	6
Brazil	5	7

National capacity building, China

- Mission of the Tianjin Institute of Industrial Biotechnology (TIB) is to "*establish a national innovation system for industrial biotechnology to promote eco-friendly development of the economy*"
- Investment in the centre: more than USD 100 million

US: DARPA Living Foundries: 1,000 Molecules Programme

- Living Foundries Program seeks to leverage synthetic biology… to create a "*revolutionary manufacturing platform*"
- Rapid design and prototyping centres to generate 1000 novel molecules and chemical building blocks, thus enabling access to radical new materials

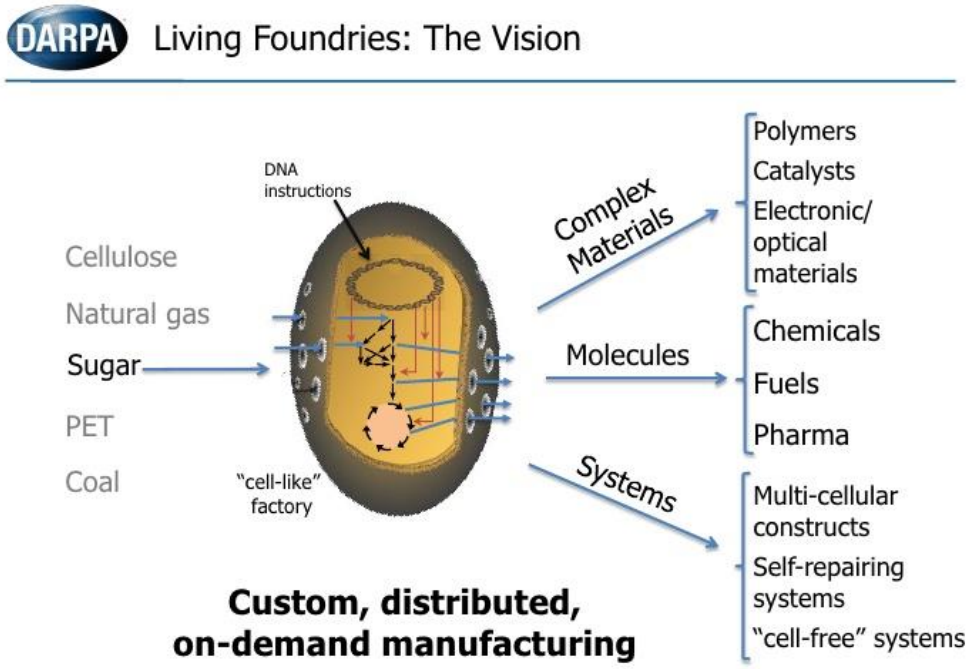


Image adapted from:
Vickers et al., Nature Chemical Biology, 2010 and Keasling, Science, 2010

Key message for Europe

- Europe *is* building capacity in industrial biotechnology
- European capacity in synthetic biology is patchy and rather *ad-hoc*

BUT

- Europe's competitors are also building capacity
  - Perhaps with more top-down coordination and strategy

Towards a European operational definition of synthetic biology

"*SynBio* (i.e. synthetic biology) *is the application of science, technology and engineering to facilitate and accelerate the design, manufacture and/or modification of genetic materials in living organisms.*"[1]

Why is the OECD interested ?

- It could be implied from this definition that synthetic biology can be used in manufacturing, and it bears relevance to the OECD definition of biotechnology which envisages "*the production of knowledge, goods and services*".

- Perhaps the field, especially public research and infrastructure funding, would benefit from an internationally agreed definition

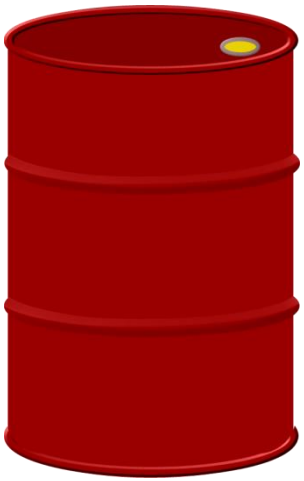
1 SCENIHR (2014). Synthetic Biology I Definition, Opinion. ISBN: 978-92-79-30136-0.

Replacing the oil barrel

Dicarboxylic acids
- Adipic
- Acetic
- Lactic
- Succinic
- 3-Hydroxypropanoic

Aromatics ?

Lower alcohols
- Ethanol
- Butanol



Thermoplastics
- Polyethylene
- Polypropylene
- PET
- PVC

Diols
- 1,3-PDO
- 1,4-BDO

Petrol
- Short-chain alkanes

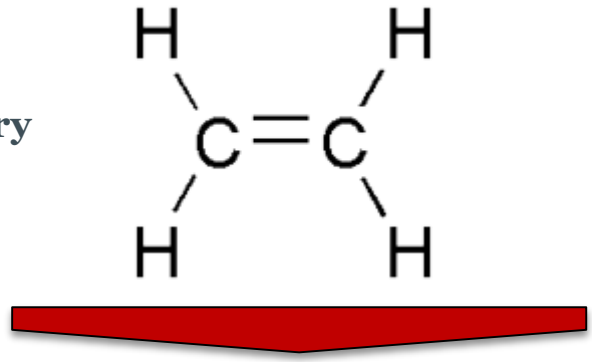
Short-chain alkenes
- Ethylene
- Propylene
- *n*-Butenes
- Isobutene
- Isoprene
- Butadiene

Diesel
- Mid-chain alkanes
- Fatty acids

Synthetic biology routes to light olefins

Today :
Fossil resources

Petrochemistry



Olefins: a group of 6 molecules that are the main building blocks in chemistry

Synthetic biology

Tomorrow :
Renewable resources

1. **Ethylene**

2. **Propylene**

3. **N-Butenes**

4. **Butadiene**

5. **Isoprene**

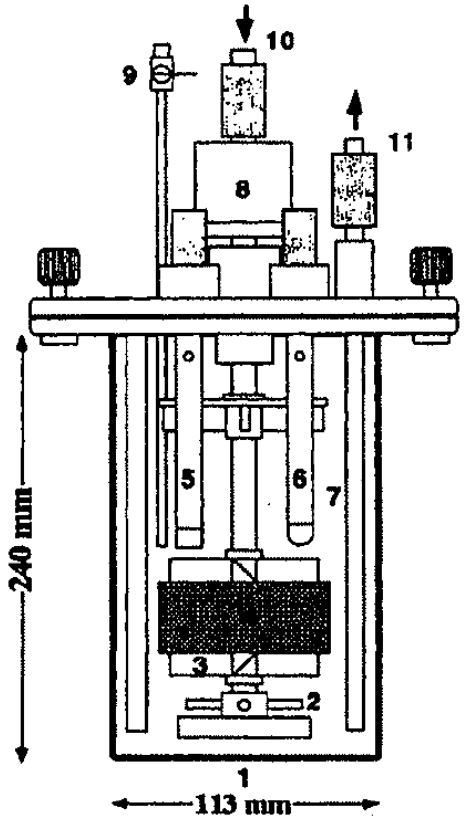
6. **Isobutene**

Courtesy of Global Bioenergies, Evry, France

Fermentation of waste gases

LanzaTech

Tanaka et al. (1995)[1]

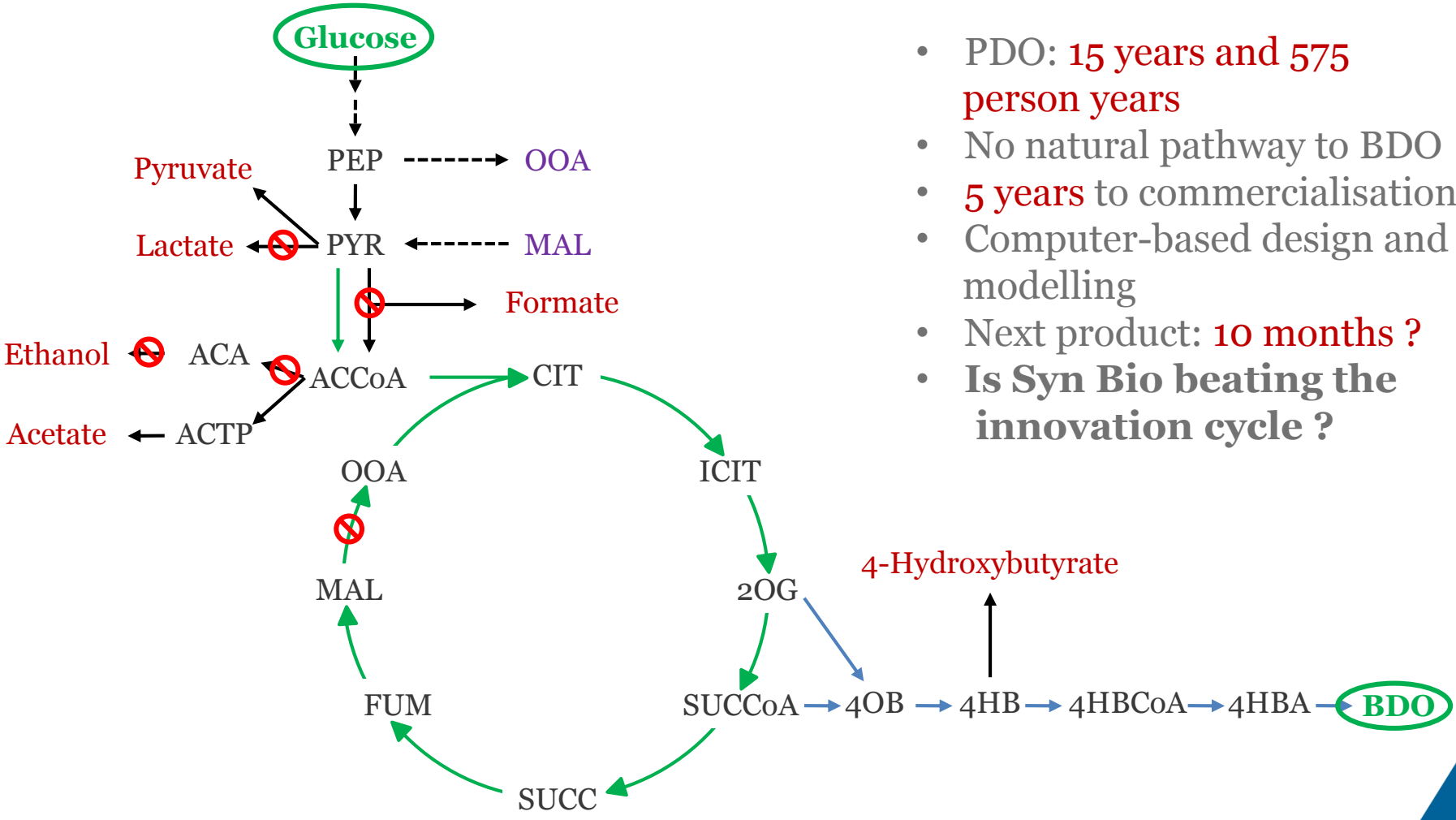


LanzaTech, 2012[2]

[1] Tanaka et al. (1995). *Biotechnology and Bioengineering* 45, 268-275.

[2] Courtesy of LanzaTech, New Zealand, www.lanzatech.com

Shortening the innovation cycle: synthetic biology's finest hour ?



- PDO: 15 years and 575 person years
- No natural pathway to BDO
- 5 years to commercialisation
- Computer-based design and modelling
- Next product: 10 months ?
- **Is Syn Bio beating the innovation cycle ?**

Yim et al. (2011). *Nature Chemical Biology* 7, 445–452.

PUBLIC POLICY ASPECTS

- **Public investments** – diversity required
- **Where does synthetic biology fit within biorefinery operations ?**
  - Need for apprenticeships ?
  - Biorefinery hubs: Bring together R&D, training, business services and pilot, demo- and full-scale production ?
- **R&D infrastructure**
  - Is there a role for local colleges ?
  - Are IROs key actors at the academic/industry interface ?
- **An updated regulatory regime**
- **SME support** through national or regional centres may be a very efficient use of public investments
- Syn Bio national or regional **roadmaps**
- **Public engagement**

Research infrastructure

- Large number of labour force gaps
- Education of synthetic biologists needs to change[1]
  - Biologists needed with more mathematical skills
  - Is the chemical engineer the role model ?
- Some countries starting to make Centres of Excellence
- Potential roadblock – Bioinformatics
- Many scattered facilities throughout Europe
  - Need coordination to cut costs e.g. IBISBA[2]

1 Delebecque & Philp (2015).
http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2015_0602/caredit.a1500143
2 www.toulouse-white-biotechnology.com/ibisba-en/

Public investments: UK example

- SynbiCITE, the Synthetic Biology Innovation and Commercialisation Industrial Translation Engine
  - $15m initial government investment,
  - Further $20m from collaborating universities and companies
- Six new multi-disciplinary Synthetic Biology Research Centres (SBRCs)
  - $35m capital investment
  - Further $80m resource funding
- Rainbow Seed Fund: $15m for start-ups, commercialise research
  - Has leveraged $225m of private investment from just $11m of its own
- Collaborative Grants for Industrial Translation
  - $10m through industry-matched funding to translate technology to new applications
- $27m to build national DNA synthesis capability and support software infrastructure
- $3m to support training the next generation of synthetic biologists

A role for IROs: VTT, Finland

From renewable feedstocks to sustainable industrial solutions

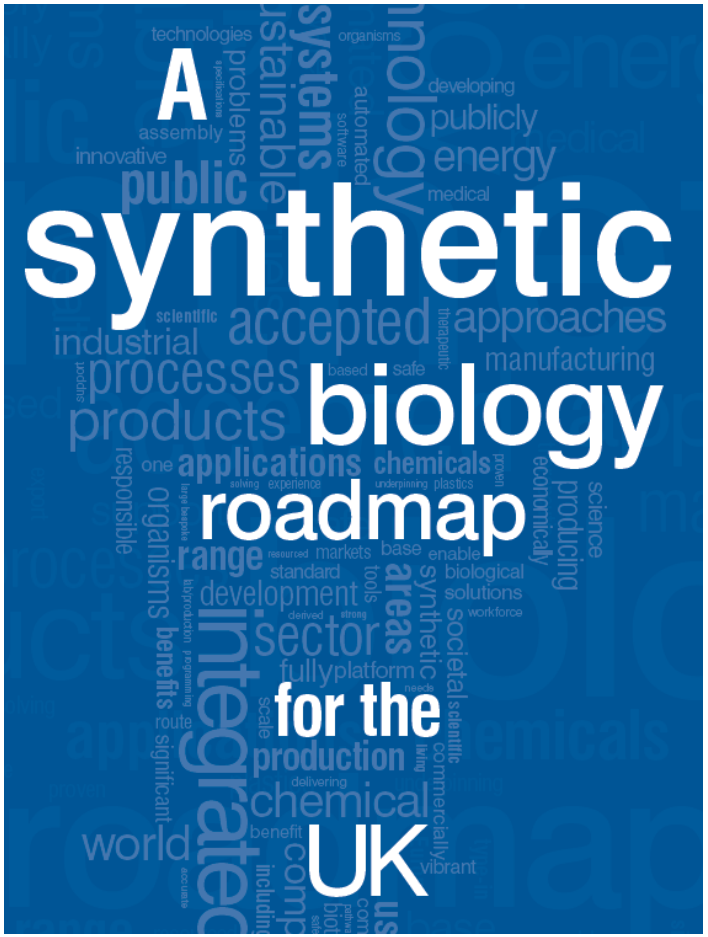
VTT BIOTECHNOLOGY OFFERING

Tailor-made production organisms | Biorefinery development | Improvement of protein production | Biotechnological utilisation of plants | Enzymes for industrial applications | Discovery of new enzymes and engineering of enzyme properties

www.vttresearch.com/services/business-essentials/pilot-plants-and-r-d-infra

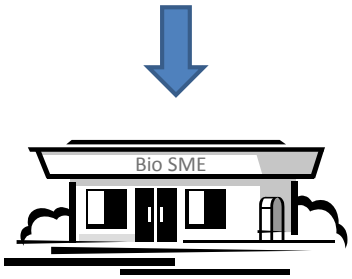
National roadmaps (and international ?)

- Invest in a network of multidisciplinary centres
- Build a skilled and well-funded UK-wide synthetic biology community
- Invest to accelerate technology to market
- Assume a leading international role
- Establish a leadership council



The shape of future manufacturing ?

DNA2.0	High throughput gene synthesis
Gen9	High throughput gene synthesis



Ingenza	Developing 2nd generation biofuels and bio-based chemicals
Mascoma	Developing synthetic biofuels
Synthetic Genomics	Synthetic life forms for biofuels and C sequestration
LS9	Developing synthetic biofuels and industrial chemicals
Amyris Biotech	Cell factories to produce medicines, fuels, industrial chemicals
Global Bioenergies	Bio-based short chain olefins

Cargill	Supports Syn Bio R&D
BP	Partnership with UC Berkeley
DuPont	Developed first commercial Syn Bio product
Pfizer	Conducts in-house Syn Bio R&D
Virgin Group	Investor in Syn Bio

DNA 2.0 · Global Bioenergies · ingenza · AMYRIS · Statoil · DUPONT · Cargill

Thank you for your time

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